An Arduino-Based Hardware Lock and Sensor Data Collection System for Cleanroom Equipment

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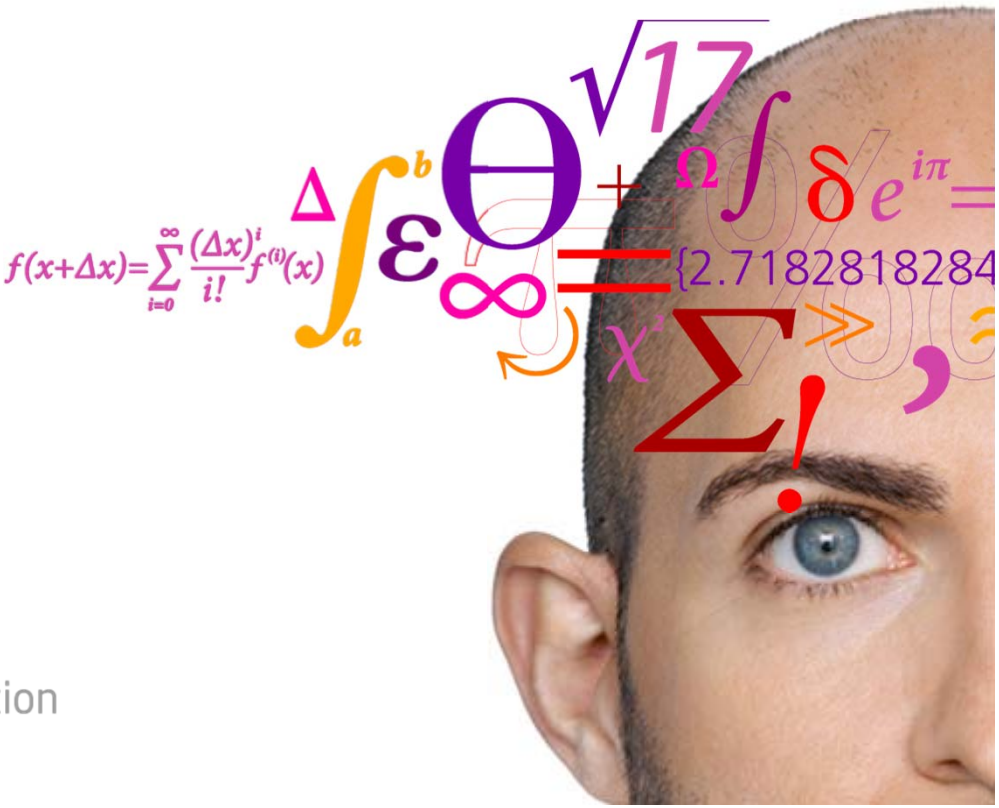


DTU Danchip
National Center for Micro- and Nanofabrication

Brief Introduction to DTU Danchip

- Danish national centre for micro- and nanofabrication, founded 1992
- A unit under the Danish Technical University (DTU)
- 40+ staff
- ISO 9001 certified since 2011
- 14 500 ft^2 (1350 m^2) class 10, 100 & 1000 space
- 250 registered users at any given time
- Ca. 140 new users per year
- 80/20% academic/commercial use
- From basic research to small-scale production
- 140+ pieces of equipment
- Pieces, 2”, 4”, 6” & 8”

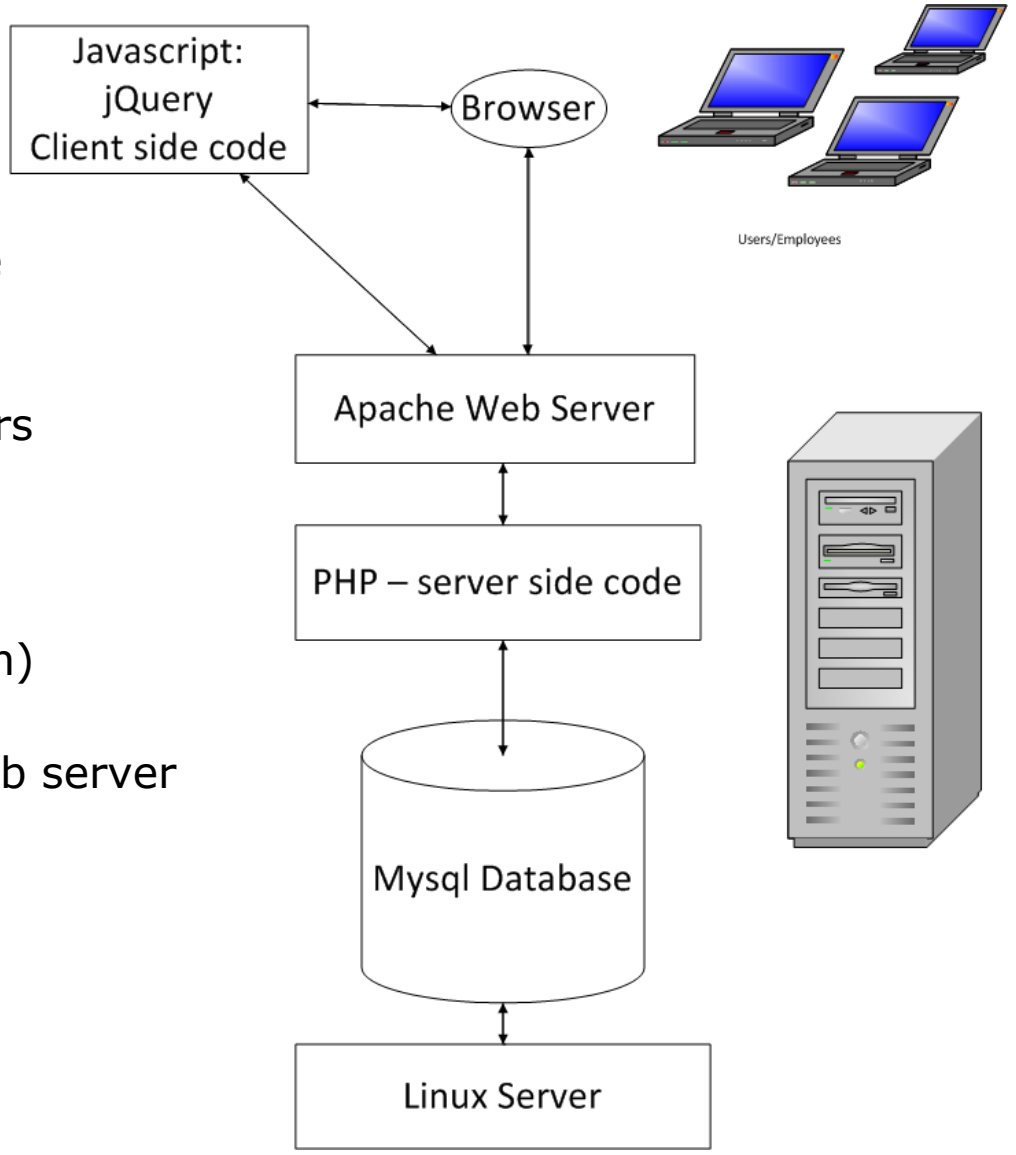
DTU Danchip, Technical University of Denmark

DTU Danchip's Payment Model

- Payment per cleanroom hour. 20 hours/month cap
- Tool usage payment
  - Class A tools (UV litho, furnaces, plating, etc.): Low fee
  - Class B tools (Thin film dep. and etch): Medium fee
  - Class C tools (DUV stepper, e-beam writer): High fee
  - Class F tools (microscopes, wet benches): Included in access fee
- Cleanroom and tool rates are depending on project type:
  - Academic: No fee
  - Academic with external funding: Reduced fee
  - Commercial: Commercial fee
- Some materials not included in tool rate: Gold, wafers & photomasks
- In the future: Expensive photoresists will be billed by consumption (1 G ZEP520: 100 000 $)
- All tool and cleanroom hours are logged via LabManager, our lab usage management system
- LabManager data forms the basis for calculation of hourly rates

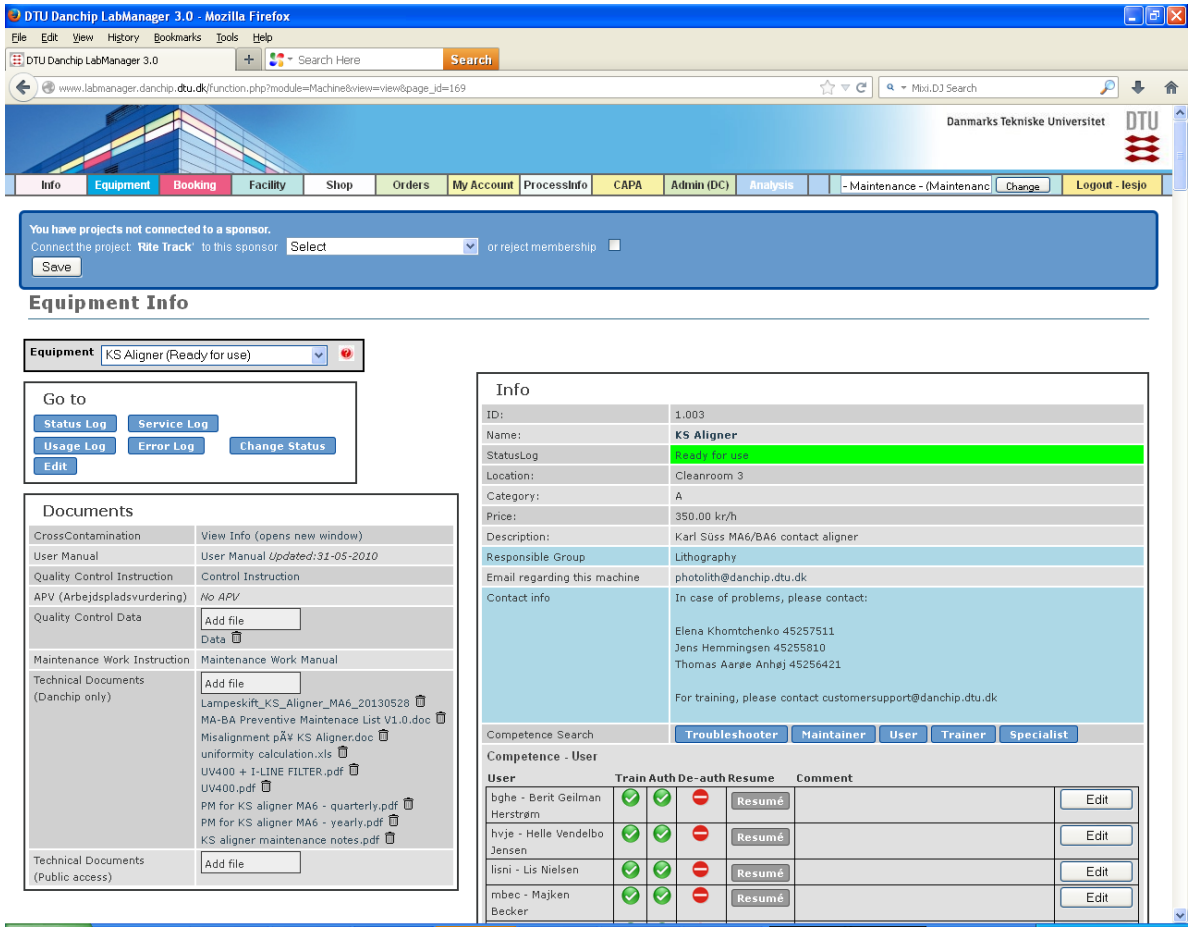
LabManager - Architecture

- LabManager: Proprietary lab usage management system
- Gradually developed over 10+ years
- Browser based
  - No s/w installation needed
  - Accessible anywhere (with login)
- Browser interfaces with Apache web server
- LabManager written in PHP
  - Not compiled
  - Easier to change code



LabManager – Functions

- Operator manuals
- Technical documents (user accessable)
- Technical documents (Danchip staff only)
- Maintenance manuals
- Safety instructions
- Contact persons
- Tool status
- Booking calendar
- Start/stop
- Logbooks (partially)
- Web shop (wafers etc.)
- Tool usage statistics
- Uptime analysis
- Bottleneck finder
- Invoicing
- CAPA handling (Danchip staff only)
- Cross contamination (upcoming)



Start / Stop

- Equipment will be put in “in use” mode on the info page
- The chosen project will be billed
- Tool usage statistics can be extracted

BUT!

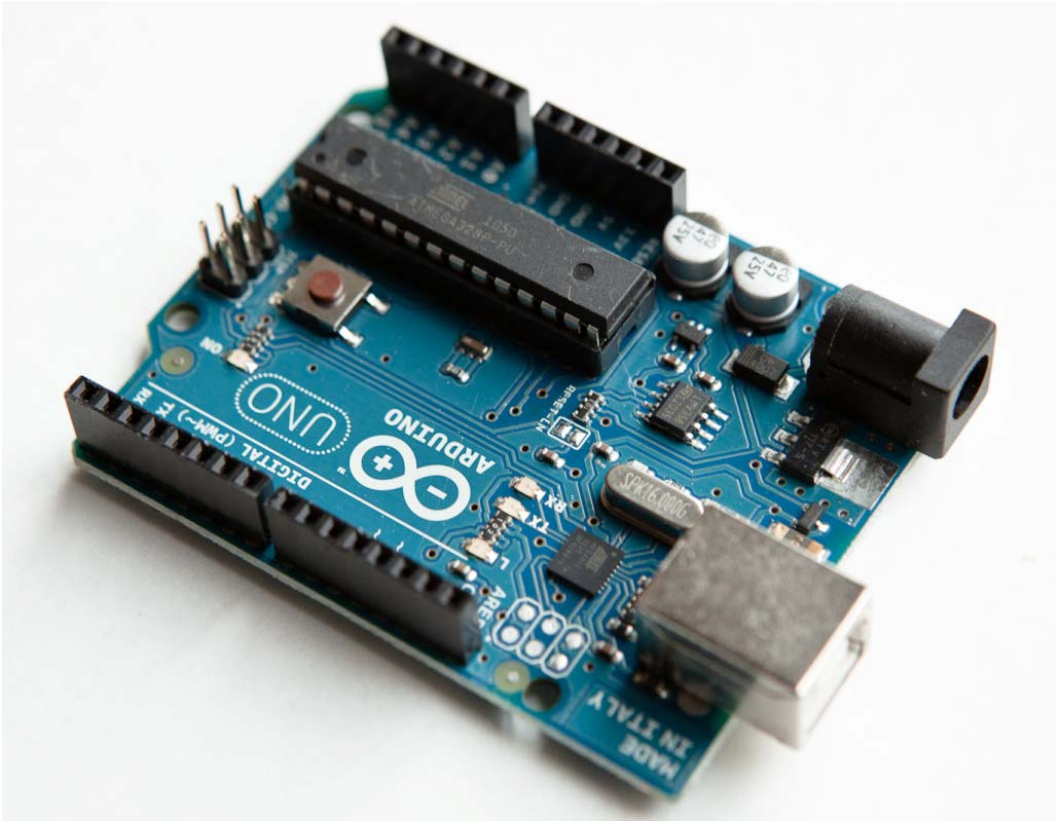
- People ”forget” to Start/Stop
- No overview over actual tool usage
  - *“Comparing log files with registrations made me lose my faith in humanity”*
- Unauthorized users accessing tools they are not trained to use
- Impossible to do proper price modelling, bottle neck analysis, etc.
- Funding of DTU Danchip jeopardized
- Unable to troubleshoot breakdowns (who did what, and when?)
- Something has to be done
- **Lock ‘em up!** (The tools – not the users)

Candidates for Hardware Lock system

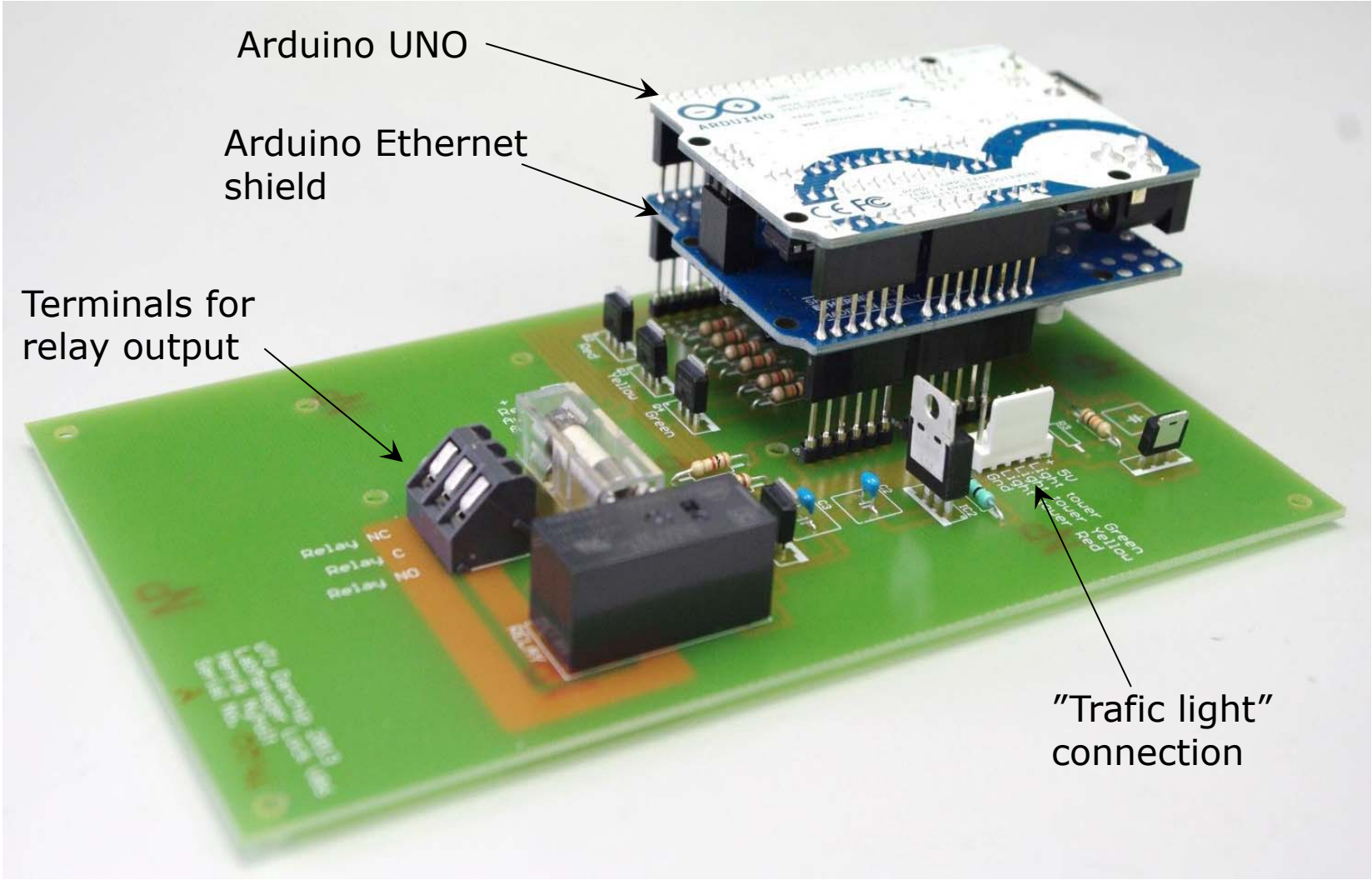
- Web IP switches:

The Arduino Microcontroller - Another Good Candidate to Build a Hardware Lock Around

- 8 bit processor
- 35 kB RAM (in flash, SRAM & EEPROM)
- 16MHz
- 14 digital I/Os
- 6 analogue inputs
- Few µW – 2.5W
- Powered over Ethernet (POE)
- Easy to program
- Price 25 USD
- More flexible than ordinary Ethernet switches
- Extra functionality



The LabManager Lock



The LabManager Lock in its Cabinet

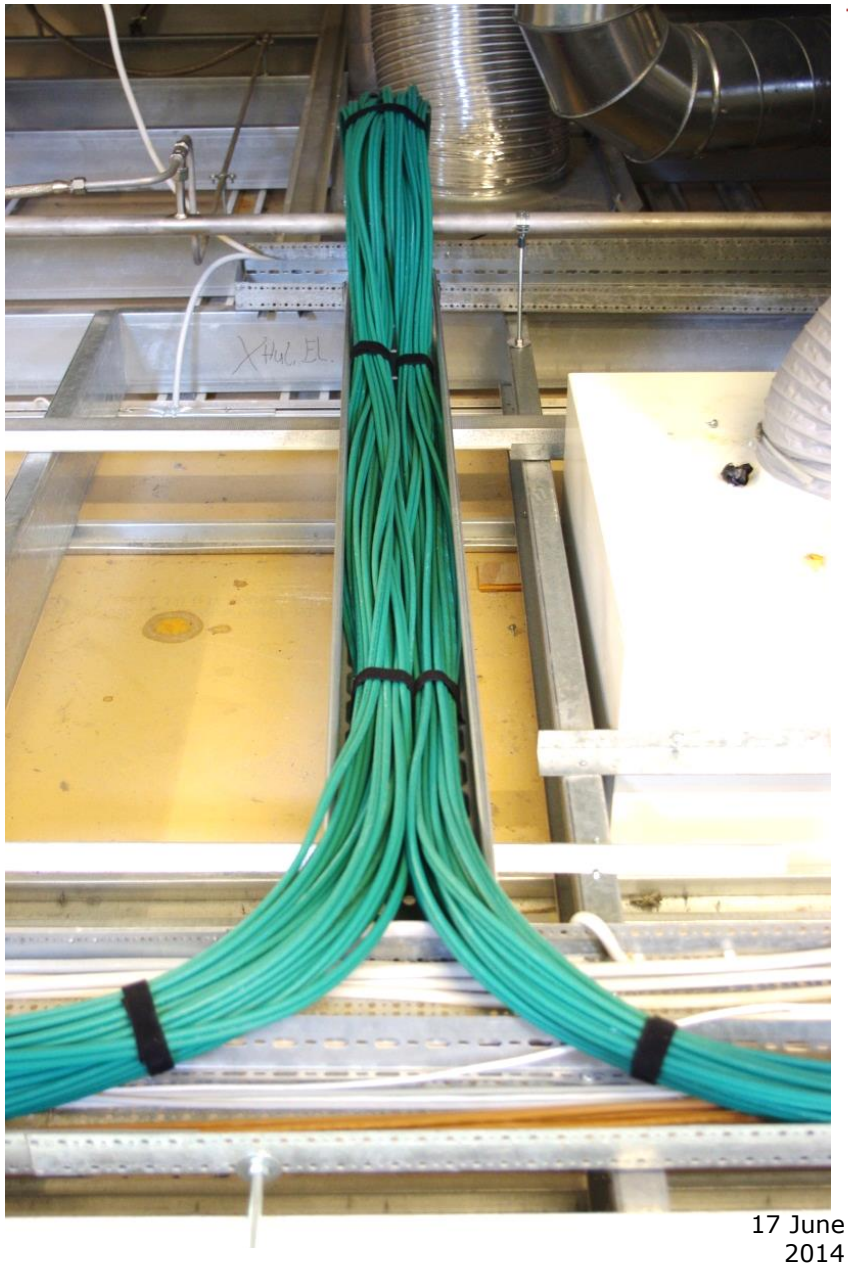
- WxHxD: 4x2.5x6 in^3 (10x7x16 cm^3)
- BOM: >100 $. More expensive than a web switch
- Assembled in house by student helpers
- Easily installable in a service area
- POE: No extra power needed
- Disable/enable
  - Screen power
  - Interlock switch
  - Shutter (aligner)
  - Power (simple tools)
  - Solenoid acuated lock
  - RF generator

Traffic Light

- Placed next to tool's user interface (PC screen, furnace door, loadlock etc.)

Infrastructure Investments: POE Cables

- 140 PDS cables, category 6A
- POE switches
- Price: Ca. 45 000 $
- Not only for LabManager locks
- Also for safety warning signs
- WLAN not preferred



LabManager Lock - Front View

DIN connector:
"Traffic light"

USB connector:
Programming

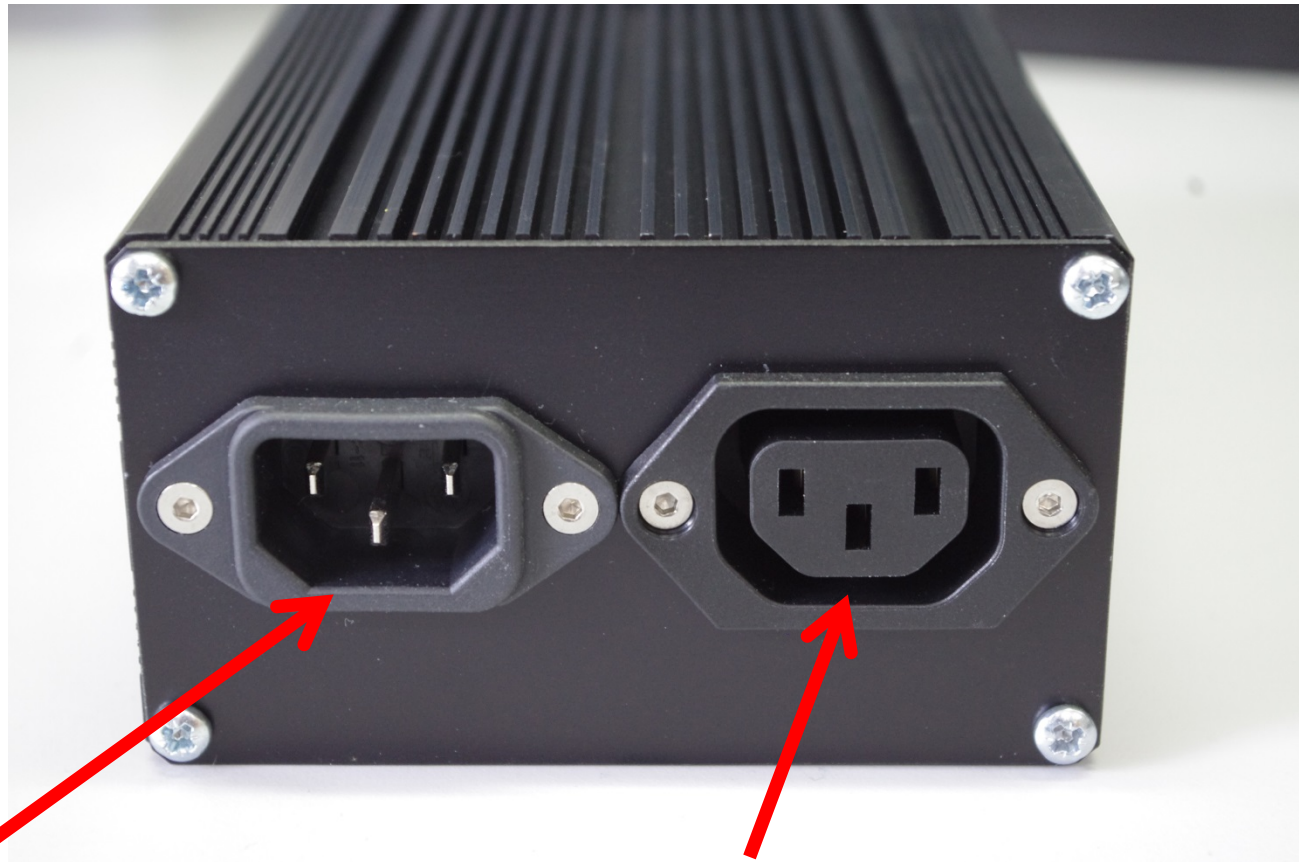
POE LAN connector:
Power and comm's

LabManager Lock - Rear View, Relay Type

Rear View – 5 V Control Signal

5 Volt control signal

Rear View, Mains Switch



Same Platform – CDA Pressure Gauge

- Portable point of use CDA pressure gauge
- CDA readouts are logged in a database via Ethernet
- Also made in a point of use vacuum gauge version

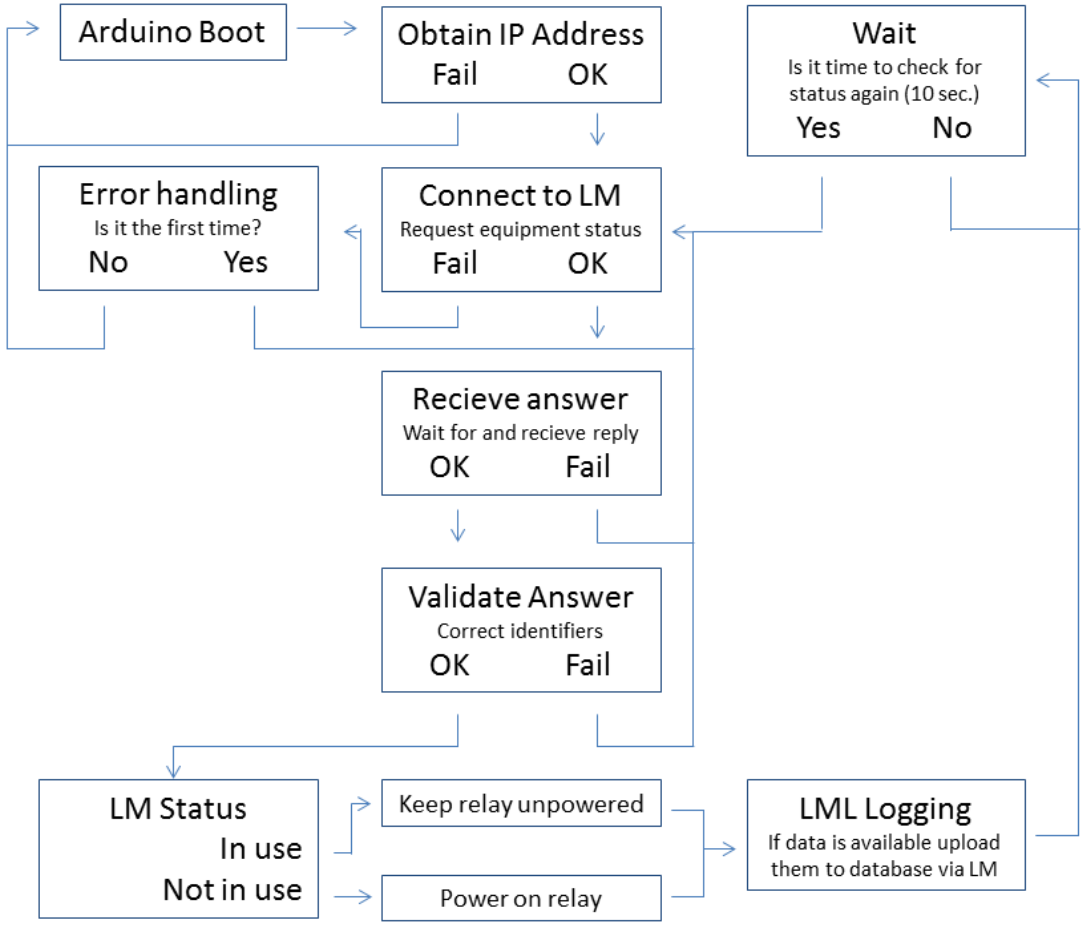
Present Project: Calculation of Resist Consumption

- DUV resist coater
- Expensive resist
- LM Lock analogue input:
  Reading of resist canister weight scale
  1. Read canister weight at tool logon
  2. Read canister weight at tool logoff
  3. Calculate resist consumption
  4. Issue bill for consumed material

- Next project: Automatic status change in LabManager via digital outputs from tool

If the Network is Down…

- Blocked equipment upsets users
- The hardware lock checks the machine's status in LabManager every 10th sec
- If the lock receives no answer from the software on status, the lock is unlocked (happy hour in the cleanroom)



LabManager - Competences

Competence - Authorized Users

User	Trained	Authorized	De-authorized	Resume
elkh - Elena Khomtchenko	✓	✓	⛔	Resumé
taran - Thomas Aarøe Anhøj	✓	✓	⛔	Resumé
makei - Matthias Keil	✓	✓	⛔	Hide

Change	Time	Changed By
authorized: *trainer*	2013-10-09 16:00:40	elkh
added Training: *trainer*	2013-10-09 16:00:38	elkh
authorized: *user*	2013-10-09 16:00:37	elkh
added Training: *user*	2013-10-09 16:00:35	elkh
authorized: *maintainer*	2013-10-09 16:00:33	elkh

- Only authorized users can start equipment
- Automatic de-authorization after 9 months without usage
- ”Bad boys” can be immediately de-authorized

Results so far

- 48 hardware locks installed 1st half 2014
- Some tools are clearly used "more" (e.g. mask aligners, hot plates, SEMs)
- Usage of some tools fluctuates– difficult to say yet
- We caught a few culprits – including "goldfinger"

Summary

- A hardware lock has been developed – built around an Arduino UNO board
- Controlled (locked/unlocked) from LabManager software
- Can only be unlocked by authorized users
- Different lock versions for different tool types
- Flexible solution capable of also reading sensor data and tool status
- Resilient to network breakdowns
- Not cheapest solution
- Maybe not for everyone

Thanks to the Guys who Did all the Real Work

- Henrik Nyholt. Basic idea concept, hardware design and construction, microcontroller programming.

- Thøger Eskildsen. PHP-programming of LabManager software.

- Jens Hemmingsen. Hardware design and construction.

Thank you for your attention...